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THE RELATIONSHIP BETWEEN SCIENCE AND THE MILITARY IN THE SOVIET UNION

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Analyzes open Soviet basic and applied science research for its possible contribution to development of military technology. As the national planner and evaluator of research and manager of the science and technology information service, the State Committee for Science and Technology cannot be entirely divorced from the early stages of military RDT&E. The reseach projects of the Academy of Sciences, USSR, include many whose exact American equivalents are either performed or funded by DOD agencies. Ten specific examples are analyzed. There seems no need for such research to be duplicated in secret military facilities, as some believe. Censorship cannot be the only reason why basic research articles so far exceed engineering development reports in number and sophistication, since this is equally true of the technology of automobiles, TV, and cameras. The Soviets are frankly anxious to publish scientific research to maintain international prestige and give their major researchers entree into meetings and conferences where useful information can be gained. 60 pp. Ref. (MW)

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The Relationship Between Science and the Military in the Soviet Union

Simon Kassel

A Report prepared for

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PREFACE

This Report was prepared within the framework of the following projects conducted at Rand for the Department of Defense:

a. A net assessment of U.S./USSR RDT&E programs, systems, and technologies, performed for the Special Assistant (Net Technical Assessment) to the Director of Defense Research and Engineering; and

b. A comparative analysis of Soviet science research, as reflected in the Soviet open-source technical literature, performed for the Director of Technology Assessments. Defense Advanced Research Projects Agency.

The study analyzes Soviet basic and applied science research from the viewpoint of its possible contribution to the development of advanced military technology, and examines the principal organizations responsible for the planning, coordination, and management of this research in relation to the military RDT&E requirements.

The discussion presented here may also be helpful to those involved in American-Soviet agreements on the exchange of scientific information and on cooperative research.

SUMMARY

The basic problem under consideration in this Report is the extent to which the Soviet Union's national science and technology establishment is involved in defense research and development. For the purpose of this study, the term "national establishment" covers the activities and institutions that are reflected in the open literature and in official statements of the Soviet government.

The investigation of the problem is pursued on two levels: (1) study of the organizational structure of the principal cognizant agencies, the State Committee for Science and Technology and the Academy of Sciences, USSR, and (2) comparison of selected research and development activities in the United States and the USSR that are discussed in the open literature of both countries. The mandate and functions of the State Committee for Science and Technology do not explicitly reveal a defense role. However, as the national planner and evaluator of Soviet scientific resources, this agency cannot be entirely divorced from those aspects of defense planning that relate to the early stages of the RDT&E cycle. More conclusive evidence of the fact that open institutions contribute to Soviet defense appears in the numerous research projects of the Soviet Academy of Sciences, whose precise American equivalents are directly supported by or actually performed within the U.S. Department of Defense.

The Academy institutes' importance to defense R&D is further enhanced by their technical control of the RDT&E cycle, which in some cases reaches well beyond the stages of basic and applied research.

Finally, the portion of the Soviet scientific and technical information system that is directly within the jurisdiction of the State Committee and the Academy indicates a topical makeup as appropriate to the needs of military research as it is to the development of national technology in general.

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I. INTRODUCTION

The attempt to evaluate the military potential of Soviet science and technology raises many questions about the Soviet scientific establishment: its substance, scope, growth rate, and resources; its organization and management; and the decisionmaking mechanism used by government authorities to control its basic policy. Since these questions have different degrees of relevance, and the difficulty of finding satisfactory answers varies accordingly, it may be useful to consider first the several categories of questions and their utility to the evaluation process. "Organizational" questions about the administrative network of Soviet R&D are obviously less direct than "substantive" questions dealing with the technical content of military research. Among the substantive questions, those concerned with the present inquire about the current weapons systems; those aimed at long-term prediction include the key question of the assessment problem: *What scientific research options are being exercised today by the Soviet military planners?* The military must make choices from the various possibilities offered by the spectrum of basic and applied science research, and some of the present choices may develop into future weapons. Organizational questions seek insight into *how* research topics are selected to meet military goals; however, for a meaningful evaluation, we need to know the answer to the substantive question of *what* these topics are.

This study attempts to relate the organizational to the substantive aspects of Soviet defense-relevant research in the areas of basic and applied sciences, with some attention also to exploratory development.

From the viewpoint of military technology assessment, problems of basic and applied sciences have a special meaning in the sense that in these areas the usual distinction between civilian and military research support is largely obliterated. For the purpose of our discussion, Soviet science and technology must always be considered in relation to the RDT&E sequence, which consists of several distinct stages. The relations between civilian and military components vary

considerably among these stages, and this dichotomy becomes very confusing when we talk about "Soviet science" without specifying the stage of the RDT&E process we have in mind.

The overall Soviet national effort in science and technology for all purposes is subject to centralized planning and control, involving top government organs and an elaborate management system. The organizational and procedural formalisms underlying that system have been examined widely and are described in the open literature. What is not readily ascertainable and clear is the extent to which the national system includes defense RDT&E. The specific question to be asked is: To what extent are the principal cognizant agencies, such as the State Committee for Science and Technology and the Academy of Sciences, USSR, involved in and how greatly do they influence defense RDT&E; or conversely, to what extent does the military influence or control the State Committee and the Academy? These two agencies, together with Gosplan and the industrial ministries, with their own research institutes determine and review the nationwide development of science and technology in the Soviet Union. The long-range plans produced by them and approved at the highest level in the government are binding on all scientific research organizations.

On the other hand, the decisionmaking process in weapons policies resides within the defense complex, as represented by the appropriate Party organs, the Ministry of Defense, and the defense industrial ministries with their research institutes.* Obviously, the State Committee and the Academy would have at best a minimal part in the development and procurement of weapons systems. However, the defense complex also originates requirements for a broad spectrum of research in basic and applied sciences with potential defense applications. And this area represents a substantial portion of the planning activities of the State Committee/Academy system. For the past decade, the annual general meetings of the Academy of Sciences, USSR, have regularly

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*An authoritative analysis of the military RDT&E decisionmaking structure was made by Fritz Ermarth, formerly of Rand.

reviewed research programs covering most of the significant topics of the science and technology spectrum. The highlights of the 1972 meeting included developments in high-power lasers, frequency-tunable lasers, fast-acting infrared image converters, high-current density superconducting cables, antifriction self-lubricating polymers, and thermally stable materials. Many of these topics clearly are of direct interest to the military.

The Soviet defense complex is not likely to be duplicating a significant part of this research in separate facilities, especially in view of the fact that the leading scientific personnel is situated in the network of open research institutes. We may, therefore, assume the existence of coordination between the defense complex and the State Committee/Academy planning system at least during the early stages of the R&D cycle. If this is correct, national plans for the overall development of science and technology must also in some way reflect defense R&D plans. This fundamental hypothesis requires testing at every opportunity.

The specific purpose of this Report, therefore, is to approach such a test by considering (1) the organizational question of national R&D in terms of the State Committee for Science and Technology, (2) the substantive question of the research contents of institutes working under the Academy of Sciences, and (3) the relation of this research to military objectives.

II. THE STATE COMMITTEE FOR SCIENCE AND TECHNOLOGY

Overall control of national research in science and technology in the Soviet Union rests with the Council of Ministers, USSR, which reviews and approves

- the main areas of development in S&T,
- development plans for S&T,
- RDT&E funding,
- basic measures to improve the management of science and technology.

In this work, the Council of Ministers draws on the resources of the State Committee for Science and Technology, which is directly subordinate to the Council. The State Committee thus appears as the key coordinating, planning, and managing body in the national science and technology effort. The duties, operations, and structure of the State Committee were described in some detail in the extensive study of Soviet science policy prepared by the Organization for Economic Co-operation and Development [1] (referred to here as the OECD study). The OECD material later was compressed and reworked by Sarah White [2]. A more comprehensive and illuminating, and perhaps the most authoritative, account of the State Committee for Science and Technology was published recently by its deputy chairman, D. M. Gvishiani, in a compendium of papers describing the Soviet R&D establishment for the benefit of the Warsaw Pact convention [3].* This analysis draws on all three as well as on other sources, with particular attention to Gvishiani's work.

The Committee for Science and Technology was established in 1965, as an immediate successor to the State Committee for the Coordination of Scientific Research, which in turn had precursor bodies dating back

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*For an outline of the evolution of State Committees charged with the planning and supervision of technological development, see Appendix A.

to 1948 [1]. Its concern has been the formulation of policy, and the planning, forecasting, coordinating, and supervising of various aspects of the RDT&E cycle in different subject areas of scientific and technical development. Varying degrees of emphasis are accorded to the individual stages of the cycle; moreover, the emphasis has shifted among the various stages during the years of operation of these organizations. Thus, the first organization, designated "State Committee for the Introduction of Advanced Technology in the National Economy," was intended to focus on the later stages of the RDT&E cycle, where the new technological developments posed an ever-present problem in the realization of their potential to modernize the Soviet industrial base. The preoccupation with this problem continued for the next decade in the "State Committee for New Technology." Not until 1957 did that Committee begin to include the word "scientific" in its title, when it became the State Scientific-Technical Committee.

The management of basic and applied science within an overall coordination of R&D is more recent. According to Gvishiani,

> . . . the notion that scientific activity does not require management is gradually eroding. At the same time, there is a growing belief in the concept that science is a complex systemic phenomenon calling for centralized management. Today, management is not merely limited to the technological applications of science, but increasingly includes even theoretical basic research [3].

The last two versions of the Committee, the State Committee for Coordination of Scientific Research (1961-1965) and the present State Committee for Science and Technology have been concerned with planning efforts covering all the stages of the RDT&E cycle, from basic research to the introduction of new technology into the economy.

The planning objectives of the Committee vary with each stage.* In basic research, planning is limited to the selection of the most promising subject areas and provision of adequate means for the activities

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*The basic planning principles for research and development are described in more detail in Appendix B.

of competent scientists and specialists. At the applied state where expenses rise significantly, planning becomes more specific. At the development stage, when expenses rise once more by an order of magnitude, planning becomes still more detailed [3].

The basic mission of the State Committee for Science and Technology is to ensure the pursuit of a "uniform state policy" in the area of scientific and technical progress, and to utilize the achievements of science and technology in the national economy [4]. To carry out this mission, the Committee is vested with certain powers and a fairly wide range of duties. These are described in detail in Appendix A; suffice it here to mention the most significant aspects of its charter so as to bring its impact on Soviet science and technology into better focus.

The official charter of an organization does not necessarily reflect the extent of its power and influence within the administrative structure in which it is imbedded. This is especially true in the Soviet Union. However, a charter can be assumed to define, if not the actual pathways of the decisionmaking system, at least the formal functions of the organization and thus the method of its interaction with the rest of the structure. Thus, the State Committee for Science and Technology, according to its charter, is the principal planner of S&T within the Soviet government, and its long-range decisions are binding on all scientific research organizations [3]. On the face of it, that wording would include *defense* scientific research organizations, although this is not explicit in the text of the charter. Nor is it clear that the State Committee is the sole promulgator of such decisions; even if it is, it could be merely serving, in certain areas, as a formal channel for decisions made by other authorities. This, then, could be its way of interacting with the decisionmaking apparatus for defense research in basic and applied sciences, as described by Ermarth.

Other, more specific functions of the State Committee as defined in its charter shed further light on its role in the decisionmaking process. These functions are of an evaluative and executive nature:

The State Committee identifies the most significant subject areas currently under development in science and technology, and forecasts future areas.*

The Committee has the power to organize and supervise entire RDT&E cycles for selected projects deemed of major national importance, and to set up and supervise the Scientific Councils that coordinate the work in specified problem areas. It also is in charge of the national S&T information service, and thereby directly controls the entire data-processing effort in science and technology as represented by the All-Union Institute of Scientific and Technical Information (VINITI), whose primary mission is the centralized abstracting of the Soviet and foreign technical literature. A central national abstracting agency may be expected to have some power to promulgate certain publishing standards and to affect publication practices. If VINITI has indeed been given such power, we may assume that the State Committee exercises a measure of indirect control over the open-source technical literature.

The selection of specific targets within the S&T spectrum for special attention, which includes the organization of entire RDT&E sequences to ensure their realization, appears to be a significant feature of the State Committee's mandate. These targets may be major problems of national significance, composed of large arrays of research projects further subdivided into individual tasks, and may originate at the beginning of the RDT&E sequence, among the basic sciences, or further down the line. The selection principle is also applied to the ongoing research projects in basic sciences and to current patent applications. Thus, the State Committee for Science and Technology, together with the Academy of Sciences, USSR, and the ministries, selects the most promising basic research efforts of the scientific research institutes and educational establishments for further progress along the RDT&E sequence. Together with the Academy and the Committee

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*The official charter of the State Committee for Science and Technology specifies "direction of development" rather than "subject area of development." This is standard usage among Soviet S&T writers, who, unlike their American counterparts, prefer a vector to a scalar concept to express the dynamics of science.

on Inventions and Discoveries, the State Committee determines the most important discoveries, inventions, and results of exploratory development and ensures their subsequent utilization [1, 3].

The Committee has at its disposal an annual reserve fund from the state budget and a reserve of scientists and corresponding wage funds which can be used for unscheduled research tasks. It can increase these reserves further during the year by canceling grants for current research that it does not deem useful, and these funds, if unused, need not be returned to the Ministry of Finance [2].

This portion of the charter of the State Committee for Science and Technology, at least on the face of it, endows the Committee with considerable power to select, stimulate, and direct the development of individual segments of Soviet research activity. The Committee appears thus to have some capability to mount crash programs in selected areas. It is not clear, however, to what extent that power is actually being exercised by the Committee, or how effective it has been. According to the OECD study, in terms of expenditures in science alone, the category of the "most important projects" (as described above) represented 56 percent in 1963 and 72 percent in 1964 [1]. Again, it cannot be established whether the entire category is effectively within the purview of the Committee.

Specialization in broad-spectrum prediction and selection of promising S&T subject areas, and proficiency in judging technological implications of scientific research, are, of course, of prime importance to the military planners, particularly if such activities and talents are based on an intimate knowledge of the available resources, scientific sophistication, and current tendencies of the national S&T establishment. In modern warfare technology, R&D support derives not only from the demands of the weapon builders but also from the appreciation of possibilities inherent in a developing science. In the United States, this is mainly the function of The Defense Advanced Research Projects Agency and other military research-sponsoring agencies, such as the Office of Naval Research, which provide the stimulus to applied and even to basic research with varying degrees of military relevance. In terms of its known charter, the State Committee for Science and Technology

in the Soviet Union has the right mixture of capabilities to perform such a function and should be very attractive to the military decision-makers for this purpose, even if one assumed that it was not originally designed with this in view.

However, the military-related functions of the State Committee are not explicit in the charter, and the extent, if any, of its operational interaction with military planners is not known. In a narrow aspect of its civilian objectives, the State Committee appears as the Soviet equivalent of the U.S. National Science Foundation. If military research objectives are indeed included in its shopping list, the State Committee can be assumed to perform some of the functions of our Defense Advanced Research Projects Agency. The problem to determine is whether and to what extent the State Committee is like ARPA, or like the NSF, or like a combination of the two. Knowing the answers is important to our understanding of the contribution from the so-called "civilian" science to the military R&D in the Soviet Union.

Some students of Soviet bureaucracy believe that the military role of the State Committee for Science and Technology is minimal. The author's former colleague Fritz Ermarth, for example, regards the Committee as merely a technical adviser to the military R&D planners. On the other hand, the OECD study indicates that the State Committee is much more defense-oriented, or that at least its predecessors were. Thus it reports:

> While the need for the promotion of R&D was certainly an important reason for the Committee's rapid rise in the Soviet hierarchy, the desire of Soviet planners to promote military research and special space programs was also a factor. Most of the Chairmen of the State Committees for Coordination created between 1947 and 1965 were top government personalities interested in armament and defense technology [1].

The question that concerns us here is not so much the "desire of Soviet planners to promote military research" as the more fundamental

one: *Can military R&D planning proceed without a close coordination with the top planning agency charged with coordinating the national R&D?** We can answer this question in the affirmative only if we assume that there is a fairly complete separation between the military and civilian sectors along the entire RDT&E sequence. Such a separation probably exists in the latter part of the sequence, and certainly in the prototype testing and production stages. It is questionable, however, whether a strict separation is maintained in basic and applied sciences, or even in the exploratory development stage. In the age of modern warfare, front-line research performed by "basic" or "applied" scientists in solid state physics, nuclear fusion and fission reactions, quantum electronics, plasma phenomena, charged particles, catalytic chemistry, biophysics, biochemistry, and a host of other subjects has in many cases a directly perceivable military potential. In some cases, this potential is obvious and strong enough to attract military interest at the outset of the research effort. For such areas we may restate our question by asking: *To what extent do the Soviets maintain separate and segregated military research facilities and top-level research personnel?*

Some insight into the problem can be obtained by a look at the activity of the Academy of Sciences, USSR, and the work of the leading Soviet research scientists that publish research results.

The Academy of Sciences, USSR, has overall control over research in the natural sciences and humanities. It also has the right to supervise the research activities of the republican academies and of the higher educational establishments [1]. The Academy and its republican counterparts also operate the top research institutes in all the hard sciences, employing the majority of the known leading scientists of the USSR. Most of the remaining scientifically prominent personnel is affiliated with the major universitites, which, as noted above, fall under the technical control of the Academy. While the

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*In the United States, the military can bypass the NSF since the latter is not an overall scientific planning agency and the extent of its functions comes nowhere near that of the State Committee. However, because of pressures from Congress and the constituencies, the U.S. military cannot ignore the NSF completely.

number of Academy institutes is relatively small as compared to the total number of research institutes in the USSR, it encompasses most of the high-prestige research organizations and probably most of the nation's facilities for basic and applied science. Together, these originate an overwhelming majority of the research papers published in the open Soviet technical literature in both regular and irregular serials.

The frequency of publication and content of these papers allow us in many cases to obtain a fairly detailed picture of the nature and scope of the individual research projects and of the quality of the personnel responsible for them.

Consequently, we shall now turn to some of the substantive aspects of Soviet research activities, as culled from descriptions of actual research found in the Soviet open-source literature, and compare them to corresponding activities in the United States.

III. A COMPARISON OF AMERICAN AND SOVIET RESEARCH PROJECTS

1. AN EXAMPLE OF A BROAD RESEARCH AREA

Laser research is one subject area suitable for such a comparison. Moreover, it has a definite potential for military applications, and it still employs a large number of applied scientists as the principal investigators.

In the United States as well as in the Soviet Union, laser research is being vigorously pursued. For over a decade, the open-source literature of both countries has shown a relatively high publication rate for this subject. Yuri Ksander of Rand made a careful count of published Soviet documents, rigidly limited to the laser field, which yielded a total of 1,800 authors of technical research reports employed in 163 research institutes for the year 1971. These scientists and organizations dedicated to laser research represent a visible Soviet work force, whose dimensions appear to be comparable to the American laser work force publishing in the open literature. To be sure, there is classified laser literature in both countries; in the United States its authors are largely the same individuals who publish the open-source papers. In view of the parallel between the two countries with respect to the open literature, there is no reason to assume that the situation is different between them as regards classified publications.

It would be of interest at this point to inquire what part of the open effort in both countries may be related to military research. To shed some light on this matter, we made a count of articles specializing in laser research and published in the *Institute of Electrical and Electronics Engineers' Journal of Quantum Electronics* for 1971, and broke them down according to the sources of support for the research on which they were reporting. Table 1 shows that 45 percent of the published papers reported on research that was either directly supported by the military or performed in the laboratories of one of the services, such as the Avionics Laboratory of the U.S. Air Force.

Table 1

SOURCES OF U.S. DOMESTIC RESEARCH SUPPORT AS INDICATED IN THE IEEE *Journal of Quantum Electronics*, 1971

Source	No. of Articles
Corporate Research, NSF, NASA	53
AEC	5
Army	9
Navy	11
Air Force	19
ARPA	8
Total	105

The 163 Soviet facilities that originated published papers in the laser field in 1971 are largely a part of the Academy of Sciences and the university network of research institutes. Military association of any kind with such facilities, if it exists, is never explicitly revealed in Soviet practice. But one would normally expect laser research to be considerably influenced by military interests regarding priorities in the prosecution of individual phases of the work, the allocation of manpower and funds, etc. The possibility of such influence in the Soviet Union is underscored by the evident military support for this work in the United States and by the fact that the Soviet papers published are in many cases the precise equivalents of the kind of U.S. research papers represented by the above table. This equivalence is best illustrated by a comparison of specific research projects carried on in the United States and the Soviet Union, rather than by a comparison of subject areas.

2. INDIVIDUAL RESEARCH PROJECTS

Tables 2 through 12 show several cases of equivalent pairs of research projects conducted in the United States and in the Soviet Union. The U.S. projects were selected if they had overt military sponsorship. The selection of the Soviet projects was based on their having the closest possible resemblance to their U.S. counterparts. The equivalence in each pair is fairly precise: Both projects deal with the

same problem and both are in the same stage of the RDT&E cycle. Also, each expresses some awareness of the other's work through citations, although the Soviet side is clearly more aware of the work in the United States than vice versa. The tables indicate the span of years during which reports on the projects were published, the names of the principal investigators, and the facilities in which the work was performed. On the U.S. side, the tables also show the military sponsoring agency; thus, an entry is made only if an explicit sponsorship statement appears in the original article. For the Soviet Union, likewise, the affiliation with a facility is given only if a by-line of the facility appears in the original article.

It is beyond the scope of this report to give a comparative analysis of each project. However, the projects shown here are the subjects of an ongoing detailed analysis by Rand staff specialists, and their technical equivalence as well as their contents, briefly described at the head of each table, reflect the analysts' findings

A. High-Energy Gas Dynamic Lasers (GDL)

Tables 2, 3, and 4 show three simultaneous phases of the work, involving a general analysis, operation of several types of GDL, and a technical methodology of GDL pumping. While each phase is being pursued in both countries, the Soviet effort indicates greater continuity of the research, which is concentrated in fewer facilities. In the United States some of this work was done with corporate or academic support, and all U.S. phases included research conducted in an in-house service facility, such as the Naval Ordnance Laboratory, or supported by the military as represented by AFWL, OAR, AFAL, and ARPA. The Soviet side of this research was performed at the Lebedev Physics Institute and the Institute of Mechanics Problems, both of the Academy of Sciences, USSR. The scientists who led the Soviet research were G. N. Basov and A. M. Prokhorov, joint recipients of the Nobel Prize for the invention of the laser itself. The Soviet projects were thus pursued under the highest scientific auspices possible in the Soviet Union, but no military association was indicated anywhere in the sources.

Table 2

OPERATING PRINCIPLES OF GAS DYNAMIC LASERS
THEORETICAL ANALYSIS AND SOME EXPERIMENTATION WITH POPULATION INVERSION METHODS BY RAPID COOLING OF GAS MIXTURES

	U.S.: 1964-1971	*USSR: 1963-1971*
Investigators	Hurle, Hertzberg, Meinzer, Kantrovitz, Anderson, Fein, Christiansen, Wisniewski	Basov, Sobolev, Prokhorov, Generalov
Facilities	Cornell Aero. Lab., AVCO, NOL, UARL, Univ. of Washington, Univ. of Illinois	Lebedev Physics Inst., Acad. Sci., USSR; Inst. of Mechanics Problems, Acad. Sci., USSR
Sponsors	NOL, AFWL, OAR, ARPA, Corporate	
References	[5-11]	[12-23]

Table 3

DESIGN AND CONSTRUCTION OF COMBUSTION- AND SHOCK-WAVE-DRIVEN cw AND QUASI-cw GAS DYNAMIC LASERS USING CO_2 AND CO

	U.S.: 1970-1971	*USSR: 1968-1972*
Investigators	Anderson, Lee, Meinzer, Bronfin, Gerry, McKenzie, Kuehn, Watt	Prokhorov, Gembarzhevskiy, Milewski, Sobolev, Dronov
Facilities	NOL, NASA-Ames, UARL, AVCO	Lebedev Physics Inst., Acad. Sci., USSR; Inst. of Mechanics Problems, Acad. Sci., USSR; Inst. Maszyn Przeptywowych (Poland)
Sponsors	AFWL, ARPA, AFAL, NASA, Corporate	
References	[25-33]	[34-44]

Table 4

METHODS OF PRODUCING POPULATION INVERSION IN SHOCK AND DETONATION WAVES

	U.S.: 1971	*USSR: 1965*
Investigators	Anderson	Orayevskiy
Facilities	NOL	Lebedev Physics Inst., Acad. Sci., USSR
Sponsor	In-house Navy	
References	[45]	[46-48]

The U.S. and Soviet efforts were closely parallel to each other, representing the same stage of the RDT&E cycle and indicating a flow of information in both directions in the form of citations. The Polish contribution to the Soviet side, made by the Instytut Maszyn Przeptywowych (Institute of Fluid Machines), is known to have direct military support from the Military Technical Academy, an educational and research arm of the Polish Ministry of Defense.

B. Optical Plasmotrons

The project in Tables 5, 6, and 7 concerns an attempt to obtain a stable laser-initiated plasma discharge in high-pressure gas, such as free air, for a number of technological uses, including possible weapons application. Soviet research on the optical plasmotron commenced much earlier than the corresponding U.S. work, which is only in the initial stage. For this reason, the Soviet theory is now being used by the U.S. researchers. The project in both countries is largely in the applied-science stage.

Table 5

FUNDAMENTAL PLASMOTRON THEORY; IONIZATION; COMBUSTION, AND DETONATION WAVES

	U.S.: 1972	*USSR: 1967-1971*
Investigators	Smith, Canavan, Neilson, Conrad, Stevering	Rayzer
Facilities	UARL, AFWL, USA BMC	Inst. of Mechanics Problems, Acad. Sci., USSR
Sponsors	In-house USAF, In-house U.S. Army, ARPA, Corporate	
References	[49]	[50-56]

Table 6

LASER-INDUCED GAS BREAKDOWN; PROPAGATION EFFECT

	U.S.: 1972	*USSR: 1964-1972*
Investigators	Smith, Canavan, Neilson, Marquet	Prokhorov, Basov, Rayzer
Facilities	UARL, AFWL, MIT Lincoln Lab.	Lebedev Physics Inst., Acad. Sci., USSR; Inst. of Mechanics Problems, Acad. Sci., USSR
Sponsors	In-house USAF, ARPA, Corporate	
References	[57, 58]	[59-63]

Table 7

LASER-GENERATED PLASMA INTERACTIONS
WITH MATERIALS

	U.S.: 1972	*USSR: 1970-1972*
Investigators	Conrad, Stevering	Min'ko
Facilities	U.S. Army, BMC	Physics Inst., Acad. Sci., Belorussian SSR
Sponsors	In-house U.S. Army	
References	[49]	[64, 65]

C. High-Current Charged-Particle Beams

Work on charged-particle beams with very high currents and energies appears to proceed at a higher level of effort in the Soviet Union than in the United States. It is aimed at specific technological applications, such as generation of millimeter and centimeter microwaves, production of high pressures in solids, production of intense burst of X-rays and gamma rays, and pumping of lasers. The performance parameters of these applications of particle beams are expected to be several orders better than those attainable by more conventional means. The direct military significance of high-current charged particle beams stems from their application to high-performance microwave radar, simulation of nuclear explosion effects, and possible use as an inertialess beam weapon. The Soviet research project stresses the collective acceleration of positive ions, as well as electrons, because of the gain in the kinetic energy and some advantages in beam neutralization in the passage through ambient gas. Since there is no restriction on the ionic species, the energy gain can be very large if heavy ions are used. Tables 8, 9, and 10 present several aspects of this work, each of which has its counterpart in the other country. In both countries, the work extends from the applied science stage, where the production and behavior of the beams are investigated, to the development and construction of devices used in the experimental program.

Table 8

DYNAMICS OF HIGH-CURRENT RELATIVISTIC ELECTRON BEAMS ON THE Mev, Ka RANGE: BEAM BEHAVIOR IN GAS, PLASMA, AND EXTERNAL MAGNETIC FIELDS: BEAM STABILITY

	U.S.: 1969-1972	*USSR: 1969-1972*
Investigators	Hammer, Rostoker, Vitkovitsky	Rukhadze, Bogdankevich, Faynberg
Facilities	Cornell Univ., ONR	Lebedev Physics Inst., Acad. Sci., USSR; Physico-technical Inst., Acad. Sci., Ukrainian SSR
Sponsors	NRL, ONR, DASA	
References	[66-68]	[69-72]

Table 9

COLLECTIVE ACCELERATION TECHNIQUES PRODUCTION AND ACCELERATION OF HEAVY-ION BEAMS

	U.S.: 1966-1971	*USSR: 1969-1972*
Investigators	Janes, Bethe, Feld, Hammer, Levine, Graybill, Uglum	Rabinovich, Kolomenskiy, Faynberg, Abramyan
Facilities	AVCO-Everett Research Lab., Ion Physics Corp., NRL	Lebedev Physics Inst., Acad. Sci., USSR; Physico-technical Inst., Acad. Sci., Ukrainian SSR; Inst. of Theoretical and Applied Mechanics, Siberian Dept., Acad. Sci., USSR
Sponsors	AFOSR, DASA	
References	[68, 73, 74]	[75-78]

Table 10

DESIGN, CONSTRUCTION, AND OPERATION OF
HIGH-CURRENT PARTICLE ACCELERATORS
FLASH X-RAY MACHINES

	U.S.: 1967-1969	*USSR: 19[illegible]-1972*
Investigators	Martin, Johnson, McNeil, Uglum, Graybill, Nablo	Pecherskiy, Tsukerman, Abramyan, Mesyats, Bugayev, Mkheidze
Facilities	Ion Physics Corp., Sandia Laboratories	Inst. of Nuclear Physics, Siberian Dept., Acad. Sci., USSR; Inst. of Atmospheric Optics, Siberian Dept., Acad. Sci., USSR; Inst. of Nuclear Physics, Electronics and Automation at Tomsk Polytechnic Inst.; Lebedev Physics Inst., Acad. Sci., USSR
Sponsors	DASA, AEC	
References	[79-81]	[78, 82-84, 108-111]

The Soviet side, in contrast to the American, shows a considerable coordination of the research activity involving several major institutions. Thus, the Lebedev Physics Institute and the Physico-technical Institute appear as the key theoretical and experimental facilities in the project, while the Siberian facilities pursue the design of advanced linear induction accelerators aiming for the reduction of the machines' overall dimensions. Of special interest is the work of the Institute of Atmospheric Optics in Tomsk, which leads in the development of advanced field-emission cathodes and specialized types of accelerators necessary for the production of these beams.

D. Detection of Underground Nuclear Explosions*

Tables 11 and 12 show two separate projects involving details of research on underground nuclear explosions.

*The Soviet open-source literature on detection of underground nuclear explosions has been analyzed by Charles Shishkevish of Rand, to whom this author is indebted for the following notes on this subject.

Table 11

THE $M_s:m_b$ DISCRIMINANT

	U.S.: 1963-1971	*USSR: 1968-1971*
Investigators	Press, Dewart, Gilman, Brunne, Espinosa, Oliver, Liebermann, King, Pomeroy, Everndeen, Filson, Capon, Lacoss, Savino, Sykes, Aki, McEvilly	Pasechnik, Dashkov, Polikarpova, Gamburtseva
Facilities	Lincoln Lab., MIT, Lamont Geol. Lab., ARPA, Columbia University	Inst. of Physics of the Earth
Sponsors	ARPA	
References	[85-90]	[91-94]

Table 12

DIFFERENCES BETWEEN SPECTRA WAVES FROM EARTHQUAKES AND UNDERGROUND EXPLOSIONS

	U.S.: 1963-1971	*USSR: 1966-1970*
Investigators	Brunne, Espinosa, Oliver, Von Seggern, Lampert, Derr, Tsai, Aki, Savino, Sykes, Liebermann, Molnar	Keylis-Borok, Pasechnik, Kogan, Sultanov, Tsibul'skiy
Facilities	Lamont Geol. Lab., Seismic Data Lab-Teledyne Industries, MIT	Inst. of Physics of the Earth
Sponsors	ARPA	
References	[96-99]	[91, 100, 101]

The principal contributor to Soviet technical literature [91-94, 100, 101], author of the monograph "Characteristics of Seismic Waves Generated by Nuclear Explosion" [94], is Doctor of Mathematical Sciences I. P. Pasechnik, the head of the Department of Detection and Identification of Explosions, one of eight departments forming the Institute of Physics of the Earth in 1963 [102].

The bulk of American nuclear detection research deals with nuclear explosions fired in the U.S.A. All aspects of Soviet nuclear explosions appear to be classified, and an undoubtedly large body of Soviet research on the subject is therefore not available. Soviet publications on detection of underground nuclear explosions deal exclusively with nuclear events fired in the United States.

The above conclusion is supported by the existence of relatively prolific literature on seismic aspects of large and small chemical explosions conducted in the Soviet Union, indicating financial support for and interest pertaining to seismic aspects of chemical explosions, and by inference also to nuclear explosions.

In his aforementioned monograph [94], Pasechnik identifies seventy-eight papers that describe results of seismological investigations conducted mostly by members of the Institute of Physics of the Earth in connection with detection of underground nuclear explosions. According to P. W. Pomeroy [102], much of the research performed at the Department of Processing of Seismic Data on Digital Computers of the Institute of Physics of the Earth, headed by Dr. V. I. Keylis-Borok, is concerned with the detection and identification of underground nuclear explosions. This group is believed to be one of the most outstanding in the Soviet Union [102]. The results of most of its research have been summarized in more than sixty articles published in five issues of the irregular publication "Computer Seismology." One-half of these articles, in the first three issues, were identified by Pasechnik as having been done in connection with research on detection of underground nuclear explosions.

Thus, while it is impossible to determine the total level of effort allocated by the Soviet authorities to the detection of underground nuclear explosions, it appears that most of the work is carried out by the Institute of Physics of the Earth of the Academy of Sciences, USSR.

Doctors Pasechnik, Keylis-Borok, and Kogan are well known seismologists and leaders in their fields. Pasechnik is generally recognized as one of the world's top specialists in seismic detection of nuclear explosions and is sometimes called upon to defend the official Soviet point of view on this subject [102]. As his country's foremost expert in this field, he represents the Soviet Union at conferences dealing with methods of detecting underground nuclear explosions, such as the meeting of experts organized by the International Institute for Peace and Conflict. He has occasionally quoted data on Soviet underground nuclear explosions which are not discussed in the open Soviet literature. The other members of the Institute of Physics of the Earth working on detection of underground nuclear explosions are also well-known experts in seismology.

The professional expertise of this group, and its explicit and documented commitment to the major aspects of underground nuclear test detection research, would tend to preclude the existence of another, parallel group of Soviet seismologists of equal stature working secretly on the problem under consideration.

Much of the work on detection of underground nuclear explosions in the United States has been funded by The Defense Advanced Research Projects Agency of the Department of Defense under the code name VELA UNIFORM. Since the inception of the program, ARPA's expenditures on this task have amounted to about 250 million dollars.

The U.S. research presented in Tables 11 and 12 was partly or wholly performed in military service laboratories or sponsored by the military service agencies. The Soviet equivalents of this research were performed by the institutes of the Academy of Sciences, USSR, or by its republican affiliates. In other words, prominent institutes on the "civilian" side in the Soviet Union carry on the same research that, in the United States, is regarded as sufficiently defense-oriented to be directly supported by the military.

The State Committee on Science and Technology, as stated in its charter, plays a definite role in planning research by subject area; in some cases it supervises the research process, which includes the work of the Academy's institutions. If a significant portion of this process constitutes military-sponsored research, the planning activity of the

State Committee must take this into account, requiring the State Committee to be cognizant of the scope and duration of the work, the projected levels of effort, the participating research organizations, etc. In other words, there has to be some degree of integration between the RDT&E plans of the State Committee for Science and Technology and those of the military decisionmakers.

Any evaluation of the role of the State Committee thus depends to some extent on our knowledge of the role played by the key research institutes. We have so far considered them mainly in terms of specific subject areas of research. Let us now turn to their relation to the RDT&E cycle.

IV. THE RDT&E CYCLE

D. M. Gvishiani, in his role as deputy chairman of the State Committee for Science and Technology, presents a fairly comprehensive theoretical breakdown of the Soviet RDT&E cycle, consisting of the following main stages and their subdivisions [3]:*

1. Basic research (*poiskovyye issledovaniya*)
2. Applied research (*prikladnyye issledovaniya*)
   a. application-oriented basic research
   b. laboratory verification and selection of alternatives
3. Development (*razrabotki*)
   a. experimental-design work (*opytno-konstruktorskiye raboty*)
   b. project-design work (*proyektno-konstruktorskiye raboty*)

The OECD study gives a similar breakdown [1], although it extends the cycle beyond development to include:

4. Production retooling for the new product
5. Introduction of the results of research into the national economy.

Gvishiani is much more specific in his definitions, which appear less academic than those of the OECD study, and more relevant to the actual problems of Soviet R&D. He thus defines the key stages of applied research and development as follows [3]:

"Applied research" is the study of methods of application of a concept or fabrication of an object, the design of appropriate equipment and machines, their principles of operation, etc. There are two subordinate stages of applied research. The first is an extension of basic research, concentrating on similar topics and employing similar

---

*The numbering of the three stages and their subdivisions is ours, not Gvishiani's.

methods, although it is no longer divorced from the concept of application. The second consists in laboratory verification of the intended utilization approaches and the selection of the most promising and reliable alternatives.

"Development" includes the actual design, construction, and testing of prototypes, preferably under conditions typical of industrial practice. The substages of development are experimental-design work and project-design work. (The two qualifiers of the term "design," in Soviet terminology, reflect a progressive approach to the final design: from design work still under experimentation, through a preliminary form of the selected alternative.)

The applied research and development stages of the Soviet cycle are roughly comparable to the U.S. stages known as 6.2, 6.3, and 6.4 and defined by the Department of Defense as follows [103]:

6.2 Exploratory Development. Effort directed toward the solution of specific military problems. May vary from fairly fundamental applied research to quite sophisticated bread-board hardware, study, programming, and planning efforts.

6.3 Advanced Development. Projects which have moved into the development of hardware for experimental or operational test. Includes design of items being directed toward hardware for test or experimentation as opposed to items designed and engineered for eventual service use.

6.4 Engineering Development. Programs being engineered for service use, but not yet approved for procurement or operation.

Table 13 shows a comparison of DOD and State Committee definitions of stages beyond basic research. The definitions correspond quite closely, except perhaps for the last stage, where the Soviet substage designated as project-design work may not necessarily bring a product to the point of service use.

The flow of work from stage to stage is a subject of controversy in Soviet technical publications. The extreme complexity of the modern RDT&E cycle is partly due to the increasing need to use sophisticated scientific techniques in the later stages, beyond basic and applied research. This is compounded by problems of work transfer from one

Table 13

COMPARISON OF U.S. AND SOVIET DEFINITIONS OF RDT&E STAGES

Stage	*Department of Defense*	*Stage*	*State Committee for S&T*
6.2	Effort may vary from fairly fundamental applied research to quite sophisticated breadboard hardware, study, programming, and planning.	2a,b	Extension of goal-oriented basic research, laboratory verification of intended utilization, selection of best alternatives
6.3	Development of hardware for experimental or operational test	3a	Design of prototypes for test or experimentation
6.4	Engineering for service use preliminary to approval for procurement or operation	3b	Project-design for construction and testing of prototypes under conditions typical of industrial practice

stage to another and of continuity of the entire cycle. Gvishiani offers an illuminating comment on this situation. He states [3] that

> Basic research is ever more concentrated in specialized scientific organizations, institutes of the academies of sciences, universities, and similar establishments. If the results of basic research promise practical solutions, there arises the problem of setting up the first stage of applied scientific development in order to clarify the utility of the concept and to sketch the main approaches to its utilization.
>
> Almost every applied problem in its first stage is closely bound with the corresponding basic research, both in methodology and substance. Furthermore, its development requires in most cases the participation of the same specialists who performed the basic research, and often also the use of a similar equipment. Therefore, it is often desirable in practice to carry out the first stage of applied research, arising directly from the results of basic research, in the same research institutes and laboratories.
>
> The second stage cannot, however, be realized without a direct participation of production specialists who can consider both the scientific and technico-economic aspects of the problem. As a rule, therefore, this stage is carried out in the appropriate branch (industrial sector) research institutes.

> However, Soviet experience shows that the greatest difficulties occur precisely at this stage, i.e., in the transfer of the work to the branch institute. This in turn frequently causes institutes engaged in basic research to carry out also all the stages of applied research. In the process, they acquire branch-type laboratories which distract them from basic research problems. Nevertheless, most research projects must be transferred at some point to specialized branch institutes.

Gvishiani holds that some participation of the pertinent basic research organization is still necessary beyond the transfer point. Thus, the organization responsible for the previous, basic research should exercise scientific control over the work subsequently performed in branch institutes and should provide the necessary aid.

The second stage of applied research is considered completed only when its product is realistically feasible and when reliable methods of practical utilization have been determined and placed on a scientific foundation. This point marks the beginning of the first development substage (experimental-design work) that is relevant to the actual production conditions. In many cases it is best to place this stage in the same industrial branch institute, or a a design bureau associated with that institute, that completed the second substage of applied research. A graphical representation of Gvishiani's version of the Soviet RDT&E cycle is shown in Fig. 1.

It is not clear to what extent the foregoing model of the RDT&E cycle and its associated procedures are typical of Soviet practice. However, considering Gvishiani's position on Soviet RDT&E and the frankness with which he discusses some of the problems, we may assume a relation between the model and the actual operation of the Soviet research establishment that is close enough to permit some inferences.

The above discussion of the Soviet research establishment brings out the strong role played by the "basic research" institutions in the RDT&E cycle. The most important of these are the institutes of the Academy of Sciences.

The main role of the Academy of Sciences in relation to the RDT&E cycle underwent basic changes through the postwar years. The most notable was the reorganization of 1961. Until then, the government

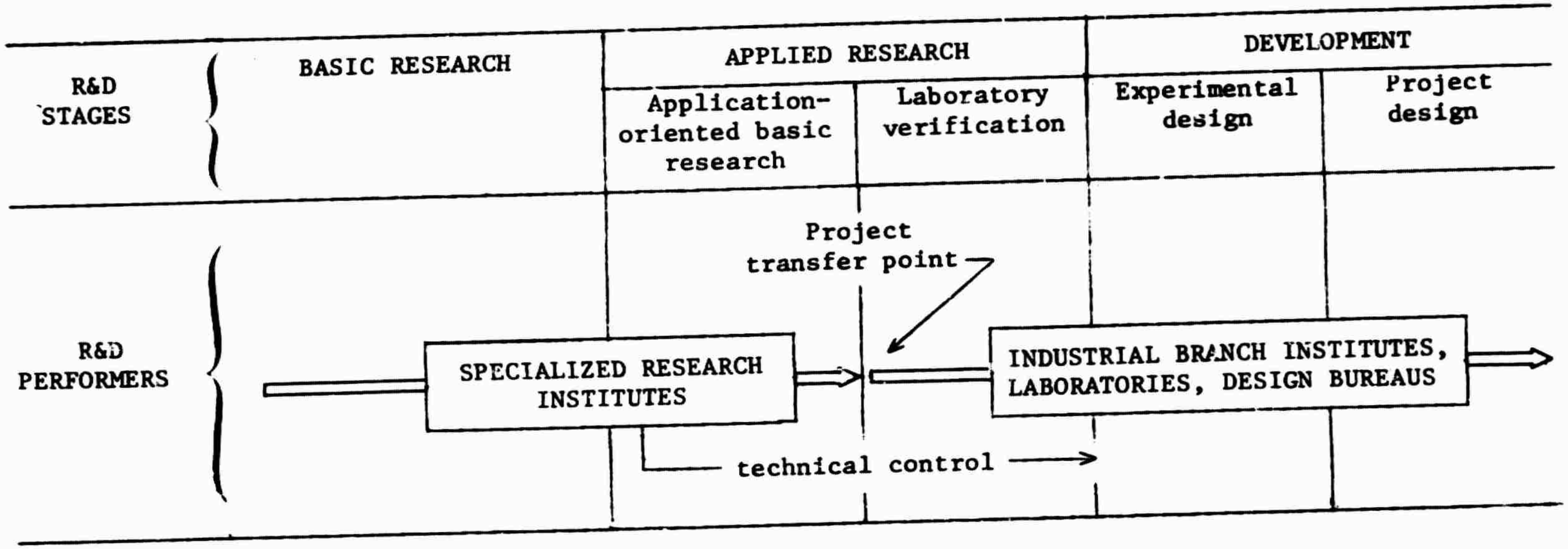

Fig. 1 -- Gvishiani's model of the Soviet RDT&E cycle

consistently emphasized applied research and industrial development as the Academy's proper tasks, although there was an equally consistent criticism that the Academy was not doing enough to foster technological progress. The 1961 reorganization limited the charter of the Academy to "natural sciences and humanities," which was tantamount to a shift toward basic research. However, the Academy was still tied to the concept of the RDT&E cycle in that it was expected to concentrate on projects capable of progressing down the cycle and was not allowed to pursue science for science's sake. Thus, according to the 1961 decree, the Academy had to work "with the aim of utilizing the results of completed scientific research for the development of the national economy and culture." The limitation to basic science research lasted only a short time, and in 1963 the Academy was again ordered to concentrate on the solution of scientific problems directly connected with the development of production [1].

This drive received a considerable impetus in 1970, when the General Meeting of the Academy placed an unprecedented degree of emphasis on the industrial utility of research work. The General Meeting is a major annual event in the organizational life of the Academy, during which the Presidium announces its policies and plans. The policy that the Academy enunciated at that meeting followed the principle that scientific development and technical projects alone could not be a measure of technological progress, and that the only proper criterion was the resulting change in the technological production base [105]. The Academy has thus become firmly wedded to the idea of goal-oriented research, closely coupled to all the stages of the RDT&E cycle if the policy is to succeed.

While the performance of the Academy in this area has been very uneven across the S&T spectrum, the capabilities of its key research institutes are considerable. In most cases, these institutes are the undisputed leaders in their specialized fields of research, mobilizing, and sometimes even monopolizing, the nation's top-level scientists and the sophisticated experimental equipment that is hard to come by elsewhere in the Soviet Union. This is particularly true of the parent body, the Academy of Sciences, USSR, with its Siberian Department, and

the Academy of Sciences of the Ukrainian SSR. The best examples of the Ukrainian Academy's influence are the Physico-technical Institute in Khar'kov and the Institute of Cybernetics in Kiev, although the Academy has many other research facilities of nearly equal stature and national significance. The Khar'kov Institute has a share of most of the key projects in physics research with a strong potential for technological application, such as high-current electron-beam production, in which it is the equal of the Lebedev Physics Institute of the USSR Academy. The Kiev Institute is the largest facility for theoretical and applied cybernetics in the Soviet Union, designer and builder of prototype high-speed computers, and a national pacesetter in industrial automation techniques.

It is clear that the research activities of the Physico-technical Institute and of the Institute of Cybernetics go beyond basic science. This is also the impression one receives from the activity range of institutes included in the comparisons of U.S. and Soviet research projects elsewhere in this report. Thus, Gvishiani's thesis about the participation of basic research organizations up to, and in some form beyond, the transfer point (see Fig. 1) appears in accord with what we know about the nature and capabilities of the key research institutes of the Academy of Sciences.

It is highly probable, therefore, that these institutes, by virtue of their scientific leadership and their well-developed experimental technology, remain in technical control of major research projects throughout the RDT&E cycle when these projects involve the participation, at some point of the cycle, of other research organizations such as the industrial branch institutes. This assumption would be valid primarily for projects initiated in the controlling institutes at the beginning of the RDT&E cycle; it would not necessarily apply to projects involving purely technological innovation or improvement and initiated in the later stages of the cycle. In cases where top-level scientists of the Academy are involved and their expertise is unique in their field, the extension of technical control by the Academy's institutes beyond the transfer point probably includes projects of military interest.

A confirmation of this hypothesis is provided in FTD Secondary Report No. 650302 [95], which describes an actual case of specialized hardware development carried out by several military R&D and production facilities under the guidance of an institute of the Academy of Sciences, USSR. The case is presented as one of many instances of such technical cooperation. In the account given in the FTD Report we thus have a situation in which a "visible" institute of the Academy of Sciences, representing basic research, is directly involved in a research project together with an "invisible" military organization, representing development and production. The Academy's institute retains overall technical control over the project, probably by virtue of the professional eminence of the institute's manpower and its superior equipment resources.

Leading scientists of high professional stature and, by Soviet standards, superior research resources are working in major institutes of the Academy of Sciences, many of which are unique in their fields of research. Practically all the specialized research fields that have, during recent years, gained worldwide prominence in physics, chemistry, and mechanical and electrical engineering have been apportioned among the Academy's institutes, each of which is the authority in its field. The situation may well be typical of all important research projects requiring high scientific expertise.

In sections II and III of this Report our analysis was concerned with three propositions: that the open-research institutes of the Soviet Union, and particularly the institutes of the Academy of Sciences, perform research projects of interest to the military; that, while their work is concentrated in the area of basic and applied sciences, they may exercise some technical supervision further down the RDT&E cycle; and that both activities may be due to the unique concentration of specialized expertise and top-level personnel they possess. A further hypothesis, dependent on the above, is that the segregated defense research institutes are not likely to maintain separate and invisible staffs of research personnel of comparable magnitude and scientific stature in the basic and applied sciences. It is reasonable to assume that segregated defense research institutes concentrate on

problems of development beyond applied science research. Their professional staffs probably consist largely of engineers and systems specialists, like the chief designer of the Soviet missile and space program, whose identity became known posthumously. The involvement the top scientists of the Academy of Sciences with the defense itutes may take many forms in addition to research, such as serving on consultative boards and committees. However, data on such connections generally are not given in the open literature. If they were available, their detailed analysis would cast further light on the network of possible ties between the visible Soviet science community and the defense establishment.

V. SCIENTIFIC AND TECHNICAL INFORMATION

The volume of publication of open-source scientific and technical serials in the Soviet Union is comparable to that prevailing in such technologically advanced countries as the United States, Britain, France, Japan, and West Germany. In the natural and exact sciences, the Soviet Union is publishing more than the United States [106]. In number of publications on technology, it is lagging behind the United States, though it is on a par with the rest of the group. The lag, however, is due in some measure to the censorship of Soviet publications.

The criteria governing the censorship that is evident in Soviet literature on science and technology are not known to this writer. What is readily apparent in this literature is the large disparity between the science and technology components, a disproportion that is both qualitative and quantitative. In general terms, the total volume and the degree of sophistication seem to be appreciably higher for scientific research papers than for those pertaining to engineering development, especially when it involves hardware. This difference is normally ascribed to censorship, which is supposed to be more stringent in the later stages of the RDT&E cycle, preventing or delaying the publication of some papers and "sanitizing" others to the point where they appear primitive. However, this may well be only a partial explanation. Qualitative and quantitative deficiency in regular serial publications is also apparent in technological areas that are ostensibly not sensitive, such as design of automobiles, radio receivers, and cameras. The volume and quality of published materials on these subjects seem far lower than those of either the Soviet scientific research literature or the technological publications of the West. It may be reasonable to conclude that this is yet another indication of the weakness of Soviet civilian technology, and that the vigorous basic and applied science research evident in Soviet literature does not percolate into the civilian technology to the same extent as happens in the West. A corollary assumption concerns the role of the Soviet military as both a stimulator and a recipient of the benefits of basic and applied science

research. Given the relative vigor of this research in the Soviet Union, which is comparable to that of the West, and the relative weakness of the Soviet civilian technology, it is possible that the Soviet military compensates in part for the deficiency of the civilian technology, stimulating as well as benefiting by the basic and applied research to a greater extent than do the Western military establishments.

If that is the case, one may ask the question, why is the Soviet literature less heavily censored in the sciences than in technology? Aside from the readily apparent answer that in the early stages of the cycle the research material is less directly related to, or indicative of, its ultimate applications, a more fundamental answer deals with the very purpose of scientific literature. This purpose is to provide an informational and educational channel to the entire scientific community, a service that is indispensable if the rank and file is to contribute to scientific progress to the limit of its potential. A large scientific establishment requires a correspondingly large channel, and no clandestine informational network could meet that purpose. Military censorship of scientific material thus comes down to a trade-off between the need to educate and the need to conceal, and the educational needs and benefits are greater, and involve a larger sector of the research population, in the basic and applied sciences than at the development and testing stages.

Another major reason for maintaining an extensive open-source literature concerns national and individual scientific prestige; Soviet authorities and scientists are quite openly and intensely anxious about that aspect of Soviet science. Their open publications, in establishing the professional standing of Soviet researchers, make it possible for them to deal on equal terms with their Western counterparts during international conferences and visits, and to obtain needed information from the West.

Censorship of Soviet publications, which for the above reasons is less evident in basic and applied sciences, has the greatest impact on the volume of open publications in technology. We can therefore assume that the actual production rate of publications in technology, including the classified material, falls at least somewhere between the U.S. rate

and that of the rest of the leading Western countries. Such a conclusion would be reasonable also in view of the relative emphasis on exact sciences and technology evident in Soviet research. The quantitative and qualitative disparity between science and technology that is evident in the open literature is not paralleled by other parameters used to measure the Soviet research establishment, such as its scientific and technical manpower. The large numbers of graduating and practicing engineers in the Soviet Union are well known [24]. Approximately 53 percent of all Soviet scientific workers are engaged in the development of technology [104]. Further evidence of this appears in the activities of the Soviet information service for science and technology.

The principal agency in this area is VINITI, or All-Union Institute of Scientific and Technical Information, established in 1952 and, after reorganization in 1955, subordinated directly to the State Committee for Science and Technology and to the Academy of Sciences, USSR [107]. This subordination of VINITI to the State Committee is in line with the latter's charter, which gives it overall direction of the national information service.

The function of VINITI includes the systematic and exhaustive abstracting of world literature in science and technology; publication of an abstracting journal, reviews, and reference literature; preparation of quick-reaction information on the subjects in greatest demand; and organization and research in methods of developing an S&T information service. The establishment of VINITI as the national information service organization has proceeded to the point where it is now the largest of its kind in the world. In 1965, VINITI already employed a full-time staff of 2,500, not counting the publishing and printing departments, and over 22,000 part-time specialist abstractors producing abstracts from 20,000 foreign and domestic journal titles [107].

Of significance is the fact that the enormous machinery of VINITI is almost exclusively concentrated in the natural sciences and technology, as shown by this list of the subject areas in which it has been active [107]:

Automation
Radio-electronics

Astronomy and geology
Biology
Geophysics
Geography
Geology
Mining
Mathematics
Mechanics
Metallurgy
Machine building
Transportation
Physics
Chemistry
Electrical and power engineering

In addition to these areas, VINITI has departments of industrial economics, science information, and science funding, but these appear to have been omitted from its abstracting activities. Altogether missing from VINITI's official purview are such subject groups as the humanities, medicine, and agriculture.

The mix of exact sciences, some natural sciences, and heavy emphasis on engineering indicate that the primary orientation of VINITI (and by inference, of the State Committee for Science and Technology) is to serve the technological development of the nation.

The scope and size of VINITI are clearly adequate for it to act as the central agency for the collection and dissemination of (at least) all open-source information for the Soviet Union's technological base, including its defense sector. VINITI's mixture of topics is entirely appropriate to that sector. Here again, therefore, we may conclude that the defense sector would have no need to maintain a separate facility for the dissemination of open-source technical literature serving military research. The State Committee for Science and Technology would thus be cognizant of the informational requirements of military-oriented research, and likely to have an appropriate administrative relationship with the military RDT&E authorities.

VI. CONCLUSIONS

The central problem considered in this study is the role of the "visible" component of the Soviet scientific establishment in the development of defense technology. Its visibility is due, first to the open-source scientific and technical literature published in the Soviet Union and, second, to the direct personal contacts between Soviet scientists and their Western counterparts. Neither the publications nor the visits provide any explicit information on the connection between the visible establishment and the military. This may be a partial reason for the view of those who minimize such a connection and believe more strongly in the possibility of a separate, and largely invisible, military scientific establishment.

The argument advanced here is that the reality of the Soviet establishment appears much more complex than the implications of that view would indicate. Separate and classified research facilities undoubtedly exist; but it seems clear that the open institutions are closely involved in defense programs. Similarly, while there is a military decision-making mechanism for control of the military RDT&E, it must operate in coordination with the leadership of national science, particularly at the earlier stages of the cycle. Soviet technical literature testifies to a high level of sophistication and pioneering in many regions of the S&T spectrum, thanks to the efforts of a large research force led by first-rank scientists. We cannot believe that the Soviet military has failed to utilize this resource to the fullest extent possible.

The most direct evidence of such utilization that is available to us is the work of the Soviet scientists itself. The comparative tables in Section III of this Report show cases where research that in the United States is supported by one or several military services is performed in the Soviet Union by the open institutes of the Academy of Sciences. This study can present only a few such examples; however, these cases are not untypical of the work of the Academy's institutes and may be regarded as representative of an appreciable portion of their

output. The institutes appear to have apportioned among themselves the research in most of the major divisions of the hard sciences and engineering. Furthermore, their research projects in these fields, as reflected to a greater or lesser extent in the literature, cover practically all the major topics of worldwide current interest.

If these research institutes and their personnel are assumed to be partially engaged in defense-oriented work, we can make some inferences about the State Committee for Science and Technology. For the activity of these scientists and their organizations fall within the purview of the State Committee, which has a statutory mandate to formulate national plans for S&T development, including specification of subject areas and major research projects.

In view of their unique professional capability, it is probable that the Academy and its institutes exercise technical control over all major research projects requiring a high degree of scientific sophistication, regardless of whether their application is civilian or military. Such control may, in some cases, continue after the development of the project has been taken over by the industrial branch institutes. It is also probable that the State Committee for Science and Technology performs administrative coordinating functions with regard to such projects and is directly involved in the preliminary planning efforts, which may include both civilian and military projects. This, however, does not imply that the State Committee for Science and Technology is necessarily the highest echelon of what Ermarth has called the "weapons policymaking apparatus." Rather, the State Committee could be regarded as having a working-level organizational arrangement with this apparatus that could reach down to the level of the research institutes. Such an arrangement would allow for the transmission, on the one hand, of research plans and requirements originated by the military and, on the other, of advisory information supplied by the State Committee. The relations between the weapons policymaking hierarchy and the State Committee would primarily lie in those areas of basic and applied science research where the visible institutes, mainly the Academy institutes, perform work of military significance.

The utility of the State Committee to the weapons policymaking apparatus may also be due to its singular capability, derived from its functions as evaluator of scientific achievement and forecaster of future areas of development. Such a capability is uniquely appropriate to military planners faced with the task of selecting options for research support.

Another area of potential usefulness to the military stems from the State Committee's function of managing the national science and technology information service. This is the principal mechanism for procuring and disseminating information on foreign S&T developments in the Soviet Union. Its scope of operation is large enough to render a separate military open-source information service highly redundant. Its emphasis on engineering and the limitation to natural sciences suggest its preoccupation with the development of the national technology base; but both characteristics also fit the needs of military-oriented research.

The assumption that the visible Soviet research organizations engaged in basic and applied sciences are participating in the defense effort points up the importance of the Soviet open-source S&T literature largely generated by these organizations. Assessment of Soviet military technology must take their activities into account. Particularly important in this respect are the activities of the key institutes of the Academy of Sciences and the research reports they regularly publish in a large number of Soviet technical journals. Analysis of these reports can yield a fairly detailed picture of the individual research projects, their level of accomplishment as well as of effort, and their objectives as to possible applications. A systematic coverage of the significant portions of the S&T spectrum in terms of such an analysis is necessary to provide an adequate demonstration of defense-relevant work. However, the relative abundance and availability of the open-source material, which today constitutes the largest single channel of information on Soviet society, renders such a task feasible. The significance of the Soviet research makes it essential.

Appendix A

EVOLUTION OF STATE COMMITTEES TO PLAN AND SUPERVISE TECHNOLOGICAL DEVELOPMENT

(Compiled from material available in sources 1 and 3)

Period: 1948-1951
Designation: State Committee for the Introduction of Advanced Technology in the National Economy
Chairman: V. A. Malyshev
Primary Mission: Introduction of new technology

Period: 1955-1957
Designation: State Committee for New Technology
Chairman: V. A. Malyshev
Primary Mission: Introduction of new technology
Coordination of research

Period: 1957-1961
Designation: State Scientific-Technical Committee
Chairman: Yu. Ye. Maksarev
Primary Mission: Introduction of new technology
Coordination of research
Investigation of foreign science and technology

Period: 1961-1965
Designation: State Committee for Coordination of Scientific Research
Chairman: M. V. Khrunichev (1961); K. N. Rudnev (1961-1965)
Primary Mission: Overall coordination of research
Duties: Authority to create new scientific establishments
Approval of the list of leading institutes
Preparation of the list of major projects
Termination of research projects
Awarding of major projects to institutions regardless of jurisdiction
Arbitration of conflicts between scientific institutions regardless of jurisdiction
Establishment of science councils (jointly with Academy of Sciences, USSR)
Approval of instructions and forms for research plans (jointly with Gosplan and Ministry of Finance)
Supervision of major projects
Introduction of new technology into national economy
Foreign research contracts
Coordinating the activities of institutions working on complex projects
Coordinating relations with foreign countries of institutes outside the Academy of Sciences, USSR

Coordinating the use of financial and material resources for research
Coordinating draft plans

Period: 1965-present
Designation: <u>State Committee for Science and Technology</u>
Chairman: V. A. Kirillin
Mission: Insuring the prosecution of a uniform state policy in the area of scientific and technical progress and pervasive utilization of the achievements of science and technology in the national economy
Duties:

1. Evaluative
   a. Identification of the main areas of national research in science and technology
   b. Technical and economic evaluation of scientific and technical development levels in the branches of industry
   c. Selection of the most promising basic research completed by the institutions of the Academy of Sciences, USSR, and republican academies, as well as the higher educational establishments (VUZ), for further development
   d. Identification of the most important current inventions, discoveries, and results of exploratory research which have not been realized in practice but which represent considerable promise for the future
2. Executive
   a. Organization of the RDT&E cycle for scientific and technical problems designated as major, and those representing the intersection of several industrial branches
   b. Taking measures to enhance the efficiency of scientific research and to insure that scientific and technical achievements are introduced into the national economy in order to maximize the economic return and to minimize the costs
   c. Supervising the introduction of scientific and technical achievements into the national economy
   d. Supervision of scientific councils on major, complex, and inter-branch problems in science and technology that perform the coordination work in the specified problem areas
   e. Use of a reserve fund from the state budget, and a reserve of scientists and corresponding wage funds, for unscheduled research work
   f. Organization of a national scientific and technical information source
   g. Cultivating contacts with foreign countries for international R&D collaboration
   h. Direction of scientific and technical propaganda and information and exhibits of national economy achievements
3. Planning
   a. Preparation of science and technology forecasts for major problems of national economy, based on systematic comparison of detailed periodic reviews on the state of the art on each division of science and on new problems and tendencies in technology

b Preparation of overall perspective plans for science and technology

c. Preparation of current draft plans for dealing with major problems in science and technology

d. Submission of plans developed under (c) to the Council of Ministers

e. Approval of coordination plans involving the entire RDT&E cycle for major problems in science and technology, designed for optimal distribution of resources along the cycle

f. Preparation in conjunction with the State Planning Commission (Gosplan), USSR, and the Ministry of Finance, USSR, of draft plans for research funding, and participation in the review of proposals submitted by the Academy of Sciences, the ministries, and agencies concerning capital investment in science

Appendix B

RESEARCH PLANNING PRINCIPLES IN THE USSR

Science development plans are classified as "perspective" (*perspektivnyye*) and "current" (*tekushchiye*) plans. The first deal mainly with future exploitation of existing discoveries. The second, as a rule, deal with exploration of new methods of application of existing knowledge. However, the controlling factor of science planning is represented by the long-range rather than short-range aims [3].

Long-range forecasting of scientific and technological progress, in conjunction with similarly long-range demographic, raw material, energy, etc. forecasts, is the basis of perspective planning of research. This is the responsibility of the State Committee on Science and Technology, which assigns specific subjects to its subordinate Scientific Problem Councils. The Academy of Sciences, USSR, participates in this work.

The perspective plans are approved by the USSR government, councils of ministers of the Union republics, and other agencies, and are binding on all scientific research organizations.

For planning purposes, RDT&E work is divided into four groups in the following order of importance [3]:

1. Work included in the all-union RDT&E plan
2. Work included in the RDT&E plan of individual republics
3. Agency RDT&E work included in the operational plans of ministries, Gosplan, and other agencies
4. RDT&E work originated by the initiative of research establishments and not approved by the above organizations

The main aim of the perspective plans is to stimulate the area of research that is recognized as the most urgent and promising. Their function is to create a flow of research projects, liquidate excessive

duplication, and ensure proper specialization of research establishments. The optimal time interval covered by the perspective plans is five years.

The composition of the perspective RDT&E plan can be illustrated by the example of the 1966-1970 project of the state plan of RDT&E work and introduction of scientific and technological achievements into the national economy:

The plan consists of the following sections [3]:

- Scientific and technical problems
- Production of new types of industrial goods
- Introduction of advanced technology, mechanization, and automation of production processes, and automated control systems
- Funding of RDT&E work
- Training of science manpower

The section "scientific and technical problems" includes particularly important problems of national economy that have been approved by the Council of Ministers, USSR. According to [1], these problems are classified as:

- Branch (improvement of production)
- Regional (development of production forces)
- Interbranch
- Interregional

The problems are subdivided into research projects, which are governed by the same classification, and further subdivided into tasks.

The 1966-1970 plan specifies the problems, as well as the research projects designed to implement the solution of the problems. The research projects specify what new types of materials, machines, equipment, instruments, products. advanced technology, and organizational methods (with indication of their most important technical characteristics) should be created and put in industrial production during the current five-year plan period.

Following the broad outline of perspective planning, current planning can be more specific. As a rule, current planning is performed directly at the level of the research organizations. In addition to more detailed expansion of the nearer stages of the perspective plan, current plans can include subjects submitted by the researchers themselves or those proposed by sponsoring enterprises [3].

Of considerable importance is the correct determination of the planning period for basic research on the one hand, and for applied research and development on the other. The most effective planning method for basic research is the long-term plan for five years or more, adjusted annually for the actual state of the work. These plans should specify not only individual projects but also comprehensive assemblies of scientific problems and principal directions of research.

The plans of applied research and development provide for annual specification of the projects, and appropriate projections for the next years to ensure continuity. These plans are more specific, stating the projects, stages of work, timetables broken down by stages, and the expected economic effect.

The large number of components entering the comprehensive problem assemblies requires the compilation of coordination plans [3]. These are developed by the ministries responsible for a uniform science policy in their appropriate branches and provide the links between the five-year plan and the annual plans for each of the five years. Together these plans cover all the stages of the RDT&E cycle and stipulate the appropriate time limits and the implementing organizations [1].

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